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NIF Projection Completion Criteria

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National Ignition Facility

March 24, 1997
NIF-0001587
WBS 1.1.5

Mr. Scott L. Samuelson
U.S. Department of Energy
Oakland Operations Office
Lawrence Livermore National Laboratory
Livermore, CA 94550

Subject: NIF Project Completion Criteria

Dear Mr. Samuelson:

At the December 18, 1996 meeting of the NIF Level 1 Baseline Change Control Board, we were asked to develop and document the criteria which will be met by the end of the NIF Project. This letter provides the completion criteria.

The complete set of NIF criteria is contained in the NIF Functional Requirements and Primary Criteria (FR/PC) [1]. These are the criteria which NIF is required to meet when fully operational. However, as we discussed at the December 18 Level 1 BCCB meeting, early operation of NIF by the Program is highly desirable and can be achieved by a phased transition to Program operations before Project completion. This enables the Program to begin experimental operations in support of Stockpile Stewardship and other programmatic missions at the earliest possible date, as NIF performance capability is building up toward the eventual goals set out in the FR/PC. This also enables a smooth Program transition from Nova experiments and ramp-up to NIF experimental activities. It ensures timely completion of the NIF Project, reasonable ramp-down of Project activity, and the limiting of Project "marching-army" costs in the out years. One of the benefits is that first Program operations at Nova energy levels occur two years before Project completion. The objective of this memo is to clarify the transition plan, by defining as precisely as possible what will be accomplished by the end of the Project.

The overall strategy for NIF construction and start-up emphasizes early start-up of a single laser system bundle. This single-bundle early start-up significantly benefits both the Project and Program. For the Project, it is an early verification of the operational capability of the basic functional unit of the laser system. For the

University of California



Program it provides early experimental capability. This first bundle of eight beamlines is installed, started up, and operated well in advance of the start-up of the rest of the laser system, to allow lessons-learned to be incorporated in the remainder of the Project production hardware. Following installation and acceptance testing of the first bundle in Laser Bay #2, the focus of Project activity will turn to installation of the full NIF system, starting in Laser Bay #1, and proceeding bundle-by-bundle. Installation of all Special Equipment in Laser Bay #1, and some of the Special Equipment in Laser Bay #2, will be conducted in parallel with operation of the first bundle. Start-up of the laser bundles in Laser Bay #1 will also begin in parallel with operation of the first bundle. The first bundle will be shut down in time to complete the installation of Special Equipment in Laser Bay #2. The installation sequence is optimized to maximize the initial operating period of the first bundle.

By the end of the Project, the status of the facility will be as follows:

- All conventional facility construction will be completed and all permanent hardware will be installed. Optical Line-Replaceable Units will be assembled and installed as required to support start-up. Acceptance tests will be performed at the subsystem level on all special equipment: laser components, structures, beam controls and diagnostics. All equipment will be integrated with the computer control system. Sufficient spares will be available for construction and initial first bundle operation.
- One bundle will have been operated sufficiently to demonstrate the basic performance capability of the system.
- The ORR will be completed.
- One-half of the laser system (the two clusters in Laser Bay #1) will be operational having completed a phased start-up sequence with demonstrated energy delivery of 5 kJ/beamline at 0.35 μ m to target chamber center. The remaining two clusters in Laser Bay #2 will be ready for start-up.

By the completion of the Project, all requirements in the FR/PC will be met, except for specific performance-related requirements as discussed in Table 1. The completion of requirements clearly depends upon the installation, start-up, and operation of all the laser systems. Full attainment of the performance goals in the FR/PC, particularly the availability requirements, will occur only after considerable operational experience has been demonstrated with the total facility. Nevertheless, careful transition planning permits the development of completion criteria for each of the mission related requirements, and these are shown in Table 1. This table lists

all the mission-related and availability goals. Check marks indicate each performance requirement that is met by the end of the project. For performance that is not fully met at the end of the project, the actual completion criteria are listed. Where indicated, the basic performance parameters will be demonstrated by extended operation of at least one bundle. The associated goals are also listed in the table.

In this manner, the Project will provide adequate assurance that the design and hardware installed will meet all NIF FR/PCs by either meeting each top-level requirement at Project completion, or by meeting a specific alternate Project completion criteria for the system (Table 1) combined with a demonstration of the key performance capability on one bundle.

Sincerely,

Jeffrey A. Paisner
Jeffrey A. Paisner
Project Manager
National Ignition Facility

Reference

[1] NIF Functional Requirements and Primary Criteria, NIF-0001006 OB, January 1997, Revision 1.5.

Attachment:
Signature Sign-Off Sheet

NIF Sign-Off Sheet

The undersigned concur with the memo entitled "NIF Project Completion Criteria" dated February 27, 1997 (attached).

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Table 1. Specific Performance-Related Requirements. Checkmarks are defined below.

Requirement title	Functional requirement	End of Project value	Single Bundle	Comments
	(clusters 1 & 2)			
2.1.1 Laser Pulse Energy	Routinely produce temporally shaped pulse of at least 1.8 MJ incident on the LEH.	500 kJ	75 kJ	Energy ramp-up commensurate with operational experience.
2.1.2 Laser Pulse Peak Power	Provide peak power of at least 500 TW.	200 TW	21 TW	Peak power will be demonstrated on a single bundle (at minimum) with short pulses (1ms). Requirement met at completion of the project.
2.1.3 Laser Pulse Wavelength	0.35 μ m	✓	✓	Power balance controls and diagnostics for all clusters will be operational. Requirement met on at least one bundle at completion of the project.
2.1.4 Beamlet Power Balance	Less than 8% rms power deviation from specified pulse over any 2 ns interval.		Less than 10% rms using simple pulse shape.	
2.1.5 Beamlet Positioning Accuracy	Rms deviation of centroids of all beams from aiming points at target plane or equivalent not to exceed 50 μ m.		Rms deviation of centroids from aiming points not to exceed 100 μ m rms at target plane.	Requirement will be met after completion of all special equipment installation activities in the LTAB, when a sufficient number of equipment calibration shots has been completed.

✓ - Requirement will be met at completion of the project.

2.1.6 Laser Pulse Duration	Overall pulse duration of up to 20 ns.	✓	✓	Requirement met at completion of the project.
2.1.7 Laser Pulse Dynamic Range	Capable of delivering pulses to the fusion target with dynamic range of at least 50:1. Dynamic range is defined as ratio of peak intensity to foot intensity.	✓ Deliver pulses with a contrast ratio over >25:1.		Full dynamic range will be achieved with extended operational experience. Requirement met on at least one bundle at completion of the project.
2.1.8 Capsule Irradiation Symmetry	2% rms variation in X-ray energy on target	✓	NA	Accomplished by appropriate design of target irradiation geometry.
2.1.9 Prepulse Power	Intensity delivered to target not to exceed 10W/cm^2 during the 20 ns interval prior to main pulse arrival.	✓	✓	Requirement met at completion of the project.
2.1.10 Laser Pulse Spot Size	Each beam shall deliver design energy and power encircled in a 600 μm diameter spot at the target plane or its equivalent.	✓ Deliver energy and power described under 2.1.1 and 2.1.2 encircled in a 600 μm diameter spot at the target plane or its equivalent.		Requirement met on at least one bundle at completion of the project.

✓ - Requirement will be met at completion of the project.

2.1.11 Beam Smoothness	Spatial and temporal beam conditioning to control intensity fluctuations in target plane.	Beam smoothing equipment installed	✓	Beam smoothing operation will have been demonstrated on at least one bundle.
2.1.12 Direct drive requirements	Future implementation of direct drive irradiation symmetry not to be precluded.	✓	✓	Target chamber port locations available to provide direct drive irradiation symmetry.
2.1.13 Beam Focusing and Pointing	Flexibility in beam focusing and pointing.	✓	✓	Requirement met at completion of the project.
2.2.1 ICF Target Compatibility	Capability of handling cryogenic and non-cryogenic targets containing fusion fuel.	✓	NA	Accomplished by appropriate design of target positioner, target chamber and target area support systems.
2.2.2 Annual Number of Shots with Fusion Yield for Chamber Design	Capable of DT fusion yield up to 1200MJ/yr. Capable of up to 50 shots /year with a routine DT fusion yield of 20MJ.	✓	NA	Complete, subject to future addition of shield doors, per BCP97-001.
2.2.4 Classification Level of Experiments	Capable of classified (at SRD level) and unclassified experiments.	✓	NA	Requirement met at completion of the project.
2.2.5 Target positioner	Target positioner operates within 3 cm of the target chamber center, requirements being consistent with 2.1.5 and 2.2.1.	✓	✓	Requirement met at completion of the project.

✓ - Requirement will be met at completion of the project.

2.2.6 Time Between Shots with No Fusion Yield	No-fusion yield shots with 8 hours in between shots, with a goal of 4 hours.	✓	✓	Total shot cycle duration for no-yield full system shots will be less than 8 hours.
2.2.7 Target Chamber Vacuum Capability	Target chamber vacuum level $<10^{-5}$ Torr.	✓	NA	Requirement met at completion of the project.
2.2.8 Diagnostic Instrument Capability to Verify Laser Performance	Specified measurement capabilities shall be provided.	✓	✓	Requirement met at completion of the project.
2.2.9 Diagnostic Instrument Capability for Ignition and Application Experiments	Capable of accommodating required diagnostics for fusion ignition and applications.	✓	NA	Requirement met at completion of the project.
2.2.10 Removal and Replacement of Diagnostics	Rapid removal and replacement, consistent with 2.2.6, shall be accomplished by diagnostic inserters and manipulators.	✓	NA	Requirement met at completion of the project.
2.2.11 Personnel Access Inside the Target Chamber	Personnel access consistent with requirements to maintain radiological, low hazard, non-nuclear operations, and for inspection and operational maintenance.	✓	NA	Requirement met at completion of the project.

✓ - Requirement will be met at completion of the project.

2.2.12 Distributed Laser Plasma Radiation Source Compatibility	Laser irradiation of distributed target arrays with future upgrade, and flexibility in beam dump placement.	✓	NA	Requirement met at completion of the project.
7.1 Reliability, Availability, and Maintainability	73% Availability 80% Reliability	NA	NA	Demonstration of RAM criteria following extended operational experience.

✓ - Requirement will be met at completion of the project.

NIF Project Completion Criteria

Physical Status

- Construction Completed (beneficial occupancy)
 - LTAB
 - OAB
 - Central Plant
 - Site Utilities
- Required Equipment in Place and Acceptance Tested
- Assembly Installation and Refurbishment Equipment (including 3 transporters and OAB equipment)
- Beampath infrastructure system for 192 beamlines
- Line replaceable units for 192 beamlines assembled, installed, and the beamlines acceptance tested
- Target Area Building and Chamber, including
 - Flexibility in Beam Dump placement (NWET)
 - Equitorial ports available to allow direct drive irradiation symmetry
 - Designed for a routine DT fusion yield of 20 MJ (50 shots/yr) with capability to withstand a maximum credible yield of 45MJ ability to perform yield shots with total DT fusion yield of 1200 MJ/yr
- Target Positioner(s) and 4 Diagnostic Instrument Manipulators (DIM)
- Diagnostics sufficient to demonstrate laser performance requirements
- Classified Data Acquisition capability and Control Room
As required to support SRD
- Project provides sufficient spares for project construction

Laser Performance Requirements

	96 Beam Performance	Single Bundle Performance
Pulse Energy	500kJ	75kJ
Peak Power	200TW	21TW
Wavelength	.35 μm	.35 μm
Positioning Accuracy	100 μm rms at target plane	100 μm
Pulse Duration	20ns	20ns
Pulse Dynamic Range	>25:1	50:1
Pulse Spot Size	600 μm	600 μm
Pre-pulse power	<10 ⁸ W/cm ²	<4 × 10 ⁶ W/cm ²
Cycle Time	8 hours max between full system shots	8 hours max between full system shots

Documentation

All documentation required to support the Defense Programs Office of the NIF Readiness Assessment

* The NIF design shall provide for life-cycle cost effective future addition of components that are needed only for high yield operation and are therefore not needed in the first 3-5 years of operation such as shield doors and decontamination equipment.